New biological data on *Fistularia commersonii* in the central Mediterranean Sea

by

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Abstract. – Preliminary data on age, growth and diet of bluespotted cornetfish *Fistularia commersonii* Rüppell, 1838 (Fistulariidae) in the central Mediterranean Sea are provided. In the study area, this invasive Lessepsian fish showed piscivorous behaviour, focusing mainly on labrids, clupeids and sparids. Prey composition suggests that bluespotted cornetfish explores various habitats for hunting. Prey fishes were mainly juveniles and their size showed positive correlation with predator size. Estimated by vertebrae readings, ages of bluespotted cornetfish, having sizes from 73.0 to 107.5 cm total length, ranged from 2 to 4 years; these are the first estimates of age for this species. The parameters of von Bertalanffy growth curves were $L_\infty = 102.39$ cm, $k = 0.49$ year^{-1}, $t_0 = -0.57$ years. The analysis of growth rates indicates that bluespotted cornetfish is a fast-growing species. Growth performance index was $\Phi' = 3.71$, and weight-length relationship, $W = 0.0001 \text{ x } TL^{3.372}$ ($R^2 = 0.857$), described positive allometric growth of *F. commersonii*.

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Résumé. – Nouvelles données biologiques sur *Fistularia commersonii* en Méditerranée centrale.

Des données préliminaires sur l'âge, la croissance et l'alimentation de l'espèce lessepsienne *Fistularia commersonii* Rüppell, 1838 en Méditerranée centrale sont présentées. Dans la zone d'étude, cette espèce invasive a un comportement piscivore, se concentrant principalement sur les labridés, les clupéidés et les sparidés, ce qui indique une exploration de divers habitats. Ces proies sont principalement des juvéniles dont les tailles sont positivement corrélées à la taille du prédateur. L'estimation de l'âge à partir des vertèbres indique des individus âgés de 2 à 4 ans pour des longueurs totales comprises entre 73,0 et 107,5 cm. Ce sont les premières estimations de l'âge de *F. commersonii*. Les paramètres des courbes de croissance de von Bertalanffy sont $TL_\infty = 102{,}39$ cm, $k = 0{,}49$ ans^{-1}, $t_0 = -0{,}57$ ans. L'analyse des taux de croissance indique que *F. commersonii* est une espèce à croissance rapide. L'indice de performance de croissance est $\Phi' = 3{,}71$, et la relation entre le poids et la longueur, $W = 0{,}0001 \text{ x } 3{,}372\ TL$ ($R^2 = 0{,}857$), décrit une croissance allométrique positive.

Key words
Fistulariidae
Fistularia commersonii
Mediterranean Sea
Age
Growth
Lessepsian

In the last century, the Mediterranean basin has been affected by invasions of non-native organisms, mostly tropical and subtropical species, from both the Red Sea through the Suez Canal and the Atlantic Ocean through the Strait of Gibraltar. This phenomenon exacerbated during the last three decades, concomitantly with increasing temperatures of Mediterranean surface seawaters, the so-called "Mediterranean tropicalization" (Andaloro and Rinaldi, 1998; Bianchi and Morri, 2003). An apparent signal of this phenomenon is pictured by non-indigenous fishes, which respond to temperature changes enlarging their populations and distribution area (Riera *et al*., 1995). About 63% of fish introductions in the Mediterranean is made of Indo-Pacific tropical or subtropical species which mainly entered the Mediterranean through immigration from the Suez Canal after its opening in 1869 (Lessepsian migration) (Andaloro *et al*., 2011). Among them, only few species have been recorded along the whole longitudinal spectrum covered by the Mediterranean. Their migration and conquest of the farthest waters from introduction sites just happened during the period of increasing temperatures, i.e. after 1980's (Rixen *et al*., 2005; Raitsos *et al*., 2010). Among the Lessepsian fish species moving westward from the eastern Mediterranean basin, only three species entered the western basin. The rabbitfish *Siganus luridus* (Rüppell, 1829) was recorded in southern Tyrrhenian Sea in 2004 (Castriota and Andaloro, 2008) and later in the Gulf of Lion in 2008 (Daniel *et al.,* 2009). The filefish *Stephanolepis diaspros* Fraser-Brunner, 1940 was recorded in the Gulf of Palermo (southern Tyrrhenian Sea) in 1983 (Catalano and Zava, 1993) and later in northern Tunisia in 2004 and 2008 (Ben Amor and Capapé, 2008. However, established populations of these two species in the western basin is not confirmed yet. Otherwise, the bluespotted cornetfish *Fistularia commersonii* Rüppell, 1838 (Fistulariidae), entered the western basin in 2003 (Pipitone *et al*., 2004) and in short time colonized all the Mediterranean, reaching the southern coasts of Spain (Sanchez-Tocino *et al*., 2007)

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after seven years from its first documented record in Israel[1] (Golani, 2000). Azzurro *et al.* (2013) estimated an invasion speed of this species in the Mediterranean varying from hundreds of km year^{-1} up to 1000 km year^{-1} and indicating low chlorophyll-a concentrations and high salinity as abiotic factors of primary importance in shaping the distribution of this species in its invaded range.

F. commersonii is an Indo-Pacific (including Red Sea) reef-associated fish, also found in sandy bottoms (Fritzsche, 1976) and in proximity of seagrass meadows (Bilecenoglu *et al.*, 2002; Pais *et al.*, 2007). Its maximum reported size is 160 cm total length although it is most commonly found up to 100 cm (Fritzsche and Schneider, 1995; Bariche and Kajajian, 2012). It lives solitary or in small groups in shallow waters up to 128 m of depth (Lieske and Myers, 1995). It feeds mainly on fishes, with minor support of invertebrates (Kalogirou *et al.*, 2007; Bariche *et al.*, 2009), adopting a high variability of hunting techniques such as stalking and chasing, either solitarily or in foraging association with con- or heterospecifics (Takeuchi, 2009). It shows camouflage activity, expressing a disruptive band pattern when stationary, but rapidly changing to a uniform silvery coloration when in motion (Thomson *et al.*, 2000). It is a multispawner species and, in the Levant Basin, it showed a prolonged reproductive season from May to October (Bariche *et al.*, 2013).

Most information on Mediterranean bluespotted cornetfish populations comes from the eastern Mediterranean where this species successfully settled and established, while in the central and western Mediterranean few studies have been carried out, mainly focusing on genetic and parasitological aspects (Golani *et al.*, 2007; Merella *et al.*, 2007, 2010; Sanna *et al.*, 2011). In Sicilian waters, since 2005 several specimens of *F. commersonii* have been captured by professional fishermen, giving the opportunity to study some aspects of its biology. In this work, we report preliminary notes on diet, age and growth of bluespotted cornetfish from the central Mediterranean.

MATERIALS AND METHODS

Specimens of *F. commersonii* were collected from January 2005 to December 2010, as by-catch of several fishing activities (i.e. trammel net, set gillnet, bottom trawl, bottom seine) in Pelagie Islands, Marettimo Island, Sciacca and Milazzo (Sicily, central Mediterranean) (Fig. 1). Each specimen was measured to the nearest millimetre (total length without filament = *TL*) and weighed to the nearest 0.1 g.

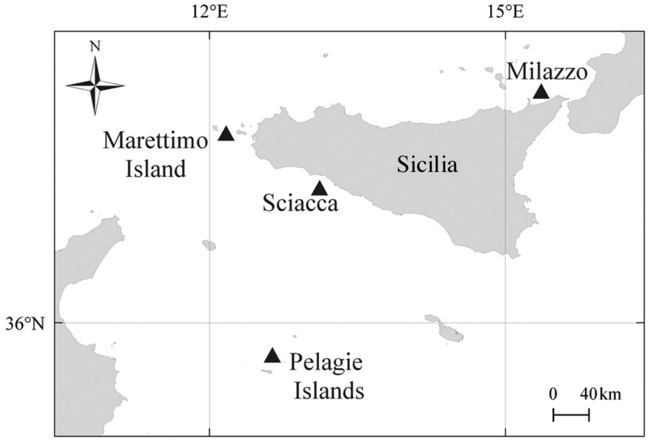

Figure 1. - Map of the study area with indication of sampling sites (▲).

Diet

A total of 77 specimens were eviscerated and their stomachs preserved in 70% ethanol for later analysis. In the laboratory, stomachs were dissected and their content analysed under a stereomicroscope. After sorting, prey items were identified to the lowest possible taxon, counted and weighed to the nearest 0.1 mg, after removing excess water with blotting paper. The count of fragmented prey was based on the number of anatomical parts traceable to single specimens (number of eyes, mouth parts, spinal columns, tails, etc.). The number of empty stomachs was recorded and used to calculate the vacuity coefficient *%Cv* (number of empty stomach/total number of analysed stomachs x 100). The contribution of each prey to the diet of *F. commersonii* was evaluated by calculating the following dietary indexes:

- percentage frequency of occurrence *%F* [number of stomachs containing prey item i/total number of non-empty stomachs) x 100];
- percentage abundance *%N* [(number of individuals of prey item i/total number of all prey items) x 100];
- percentage weight *%W* [(weight of prey item i/total weight of all prey items) x 100];
- index of relative importance (*IRI*), using mass instead of volume: $IRI = (\%N + \%W)\%F$ (Hyslop, 1980; Hacunda, 1981);
- percentage index of relative importance *%IRI [(IRI / ∑ IRI)* x 100].

Prey size was measured to the nearest 1 mm and correlated with predator size by regression analysis and tested with Student's t-test (Snedecor and Cochran, 1967).

Age

Vertebrae were used for the age estimation of *F. commersonii*, since otoliths were breakable and difficult to read. Estimates of size-at-age were carried out on 46 specimens whose vertebrae were preserved. Thoracic vertebrae were preferred to the usually employed caudal ones because of their larger *centrum* size and easier readability. Up to 10 thoracic vertebrae were extracted from each specimen, cleaned from fleshy parts after immersion in boiling water and deprived of neural and hemal spines. The intact *centra* were cleaned of gelatinous tissue by scratching gently, they were stained with alizarin red in a solution of NaOH and glycerine for 4-8 hours, washed, dried and stored with a code number (Morales-Nin *et al*., 1999). Stained vertebrae were examined with a stereomicroscope under reflected light. They displayed distinct alternating light and dark rings. Even if it was not possible to carry out any age validation, dark and light ring formation seems to follow the classic annual growth of fish from temperate waters. Then, it was assumed that each set of one dark and one light ring may represent an annual growth zone. The vertebral ring-count was given by the number of complete growth rings observed. At least four vertebrae for each specimen were read and growth increments were independently counted by two operators in order to limit interpretation mistakes. As a rule, when readings were discordant, a second observation was carried out and if this last reading still provided different results, the vertebra was rejected.

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[1] The first sighting of *Fistularia commersonii* dates back to 1999 in Cyprus (Katsanevakis *et al.*, 2009) but no specimen was preserved.

Growth

Growth parameters (TL_∞, k, t_0) were estimated by fitting age and related length data into the theoretical growth model of von Bertalanffy (1938):

$$TL_t = TL_\infty\,[1 - e^{-k\,(t - t_0)}]$$

where TL_t is the total length at age t (years), TL_∞ is the predicted asymptotic length, k is the instantaneous growth coefficient, describing how rapidly this length is achieved, t_0 is the theoretical age at zero length (years). Finally, the growth performance index ($\Phi' = 2 \log TL_\infty + \log k$) (Munro and Pauly, 1983) was also calculated.

The weight-length relationship was calculated on 60 specimens using the potential equation (Ricker, 1975):

$$W = a\,TL^b$$

where W is the total weight (g), TL is the total length (cm) without filament, a is the intercept of the regression line and represents a coefficient related to the body shape of the species, b is the regression coefficient and indicates the isometric growth when equal to 3 (Wootton, 1990; Anderson and Neumann, 1996). The parameters a and b were estimated by linear regression analysis on *ln*-transformed data. To check the theoretical isometric ($b = 3$) or allometric growth ($b \neq 3$) the Student's t-test (Snedecor and Cochran, 1967) was employed.

RESULTS

Diet

Out of 77 individuals examined, 49 had empty stomachs (*%Cv* = 63.6). Specimens ranged from 69.2 to 107.5 cm *TL* (80.3 ± 7.5 cm). Stomach contents analysis led to the identification of 15 prey items, all belonging to teleosts, for a total weight of 60.76 g. The values of dietary indexes of the identified prey items are listed in table I. *Sardinella aurita* Valenciennes, 1847*, Serranus cabrilla* (Linnaeus, 1758) and *Boops boops* (Linnaeus, 1758) were the most frequent species (*%F* = 10.3). The clupeid *S. aurita* resulted the most important prey in terms of mass (*%W* = 24.3), abundance (*%N* = 10.4), and *%IRI* (32.7). *Boops boops* represented the second important species (*%IRI* = 16.5). Values of *%IRI* calculated per prey family highlighted the importance of

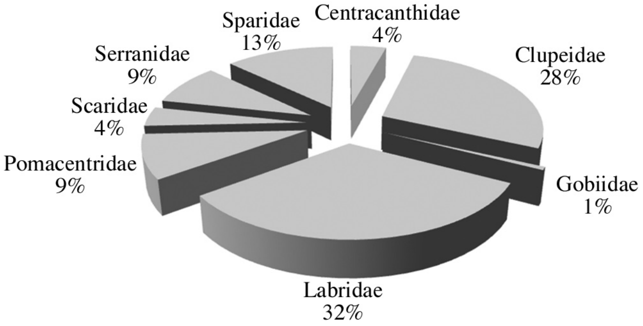

Figure 2. - Percent index of relative importance (*%IRI*) calculated per prey family in the diet of bluespotted cornetfish.

Table I. Diet composition of *Fistularia commersonii* in the central Mediterranean Sea and dietary indexes calculated for each prey item: percent frequency of occurrence *(%F)*, percent of total number (*%N*), percent of weight (*%W*), and percent index of relative importance (*%IRI*).

Family	Species	%F	%N	%W	%IRI
Centracanthidae	*Spicara flexuosa* Rafinesque, 1810	3.4	2.1	8.1	3.2
	Spicara smaris (Linnaeus, 1758)	3.4	2.1	3.6	1.8
Clupeidae	*Sardinella aurita* Valenciennes, 1847	10.3	10.4	24.1	32.7
Gobiidae	Unidentified Gobiidae	3.4	2.1	0.4	0.8
Labridae	*Coris julis* (Linnaeus, 1758)	6.9	4.2	2.4	4.1
	Symphodus ocellatus (Forsskål, 1775)	6.9	4.2	6.5	6.7
	Symphodus sp.	3.4	2.1	0.8	0.9
	Thalassoma pavo (Linnaeus, 1758)	3.4	4.2	12.5	5.3
	Unidentified Labridae	3.4	2.1	0.0	0.7
Pomacentridae	*Chromis chromis* (Linnaeus, 1758)	6.9	4.2	13.1	10.9
Scaridae	*Sparisoma cretense* (Linnaeus, 1758)	3.4	2.1	13.2	4.8
Serranidae	*Serranus cabrilla* (Linnaeus, 1758)	10.3	6.3	4.7	10.4
Sparidae	*Boops boops* (Linnaeus, 1758)	10.3	8.3	9.0	16.5
	Pagellus sp.	3.4	2.1	1.4	1.1

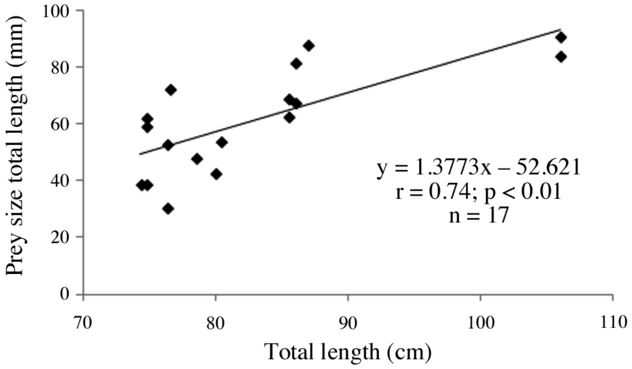

Figure 3. - Regression analysis performed between prey size and bluespotted cornetfish size.

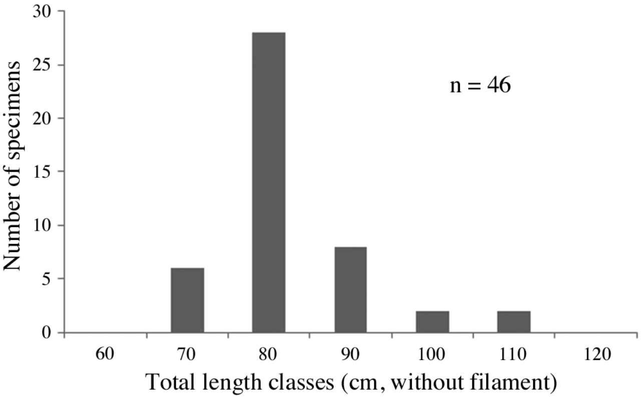

Figure 4. - Length-frequency distribution of bluespotted cornetfish considered for age analysis.

Table II. - Age-length key of *Fistularia commersonii* in central Mediterranean Sea.

TL (cm) Classes	Range	Age classes			Total
		2	3	4	n
70	66-75	6			6
80	76-85	10	17	1	28
90	86-95		4	4	8
100	96-105		1	1	2
110	106-115			2	2
n		16	22	8	46
Mean TL		75.77	82.62	94.35	
SD		1.75	4.29	9.83	

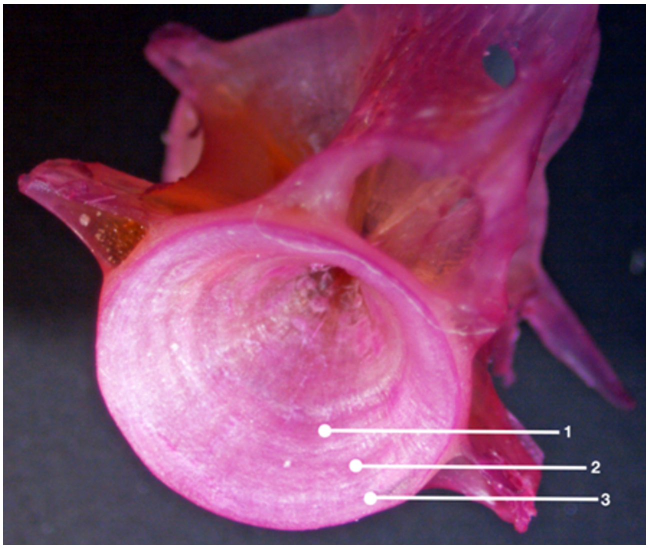

Figure 5. - Example of age reading in a vertebra of an estimated 3-years old specimen of *Fistularia commersonii*.

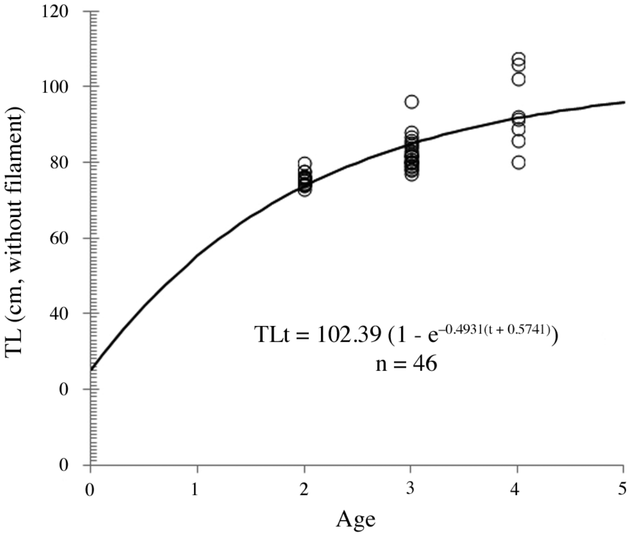

Figure 6. - Von Bertalanffy curve determined from growth increment interpretation in *Fistularia commersonii* vertebrae.

labrids, followed by clupeids and sparids in the diet of bluespotted cornetfish (Fig. 2). Prey size ranged from 30.5 to 91.3 mm *TL*. Regression analysis performed between prey size and predator size revealed a highly significant correlation ($t_{15} = 4.25$; $p < 0.01$), with Pearson's coefficient $r = 0.74$ (Fig. 3).

Age

The specimens of bluespotted cornetfish considered for the age analysis ranged from 73.0 to 107.5 cm *TL* (82.3 ± 8.1 cm). Figure 4 shows the length frequency distribution of these specimens; 61% of samples belong to the 80 cm *TL* class (75-85 cm).

Out of 200 vertebrae analysed, only three were considered unreadable. The thoracic vertebra of *F. commersonii* shows a conical *centrum* with bands made of widely spaced rings in the inner part, becoming progressively narrow in the outer part. Age readings allowed to identify three age groups, presumably belonging to fish of 2, 3 and 4 years old. The age composition of the individuals considered in this study in relation to length (age-length key) is summa-

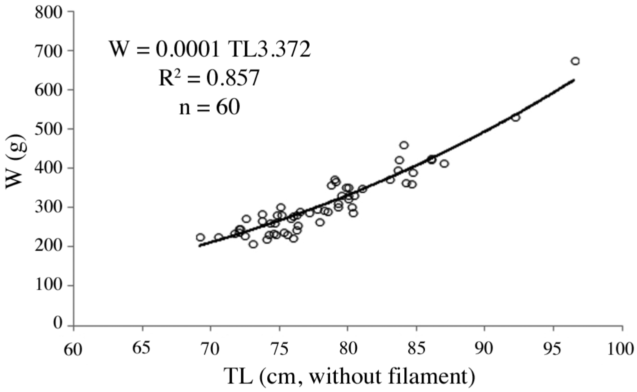

Figure 7. - Length-weight relationship for *Fistularia commersonii*, central Mediterranean Sea.

rized in table II. The majority of samples belonged to the length class 75-85; in particular, 16 specimens (34.7%) were included in age class 2 ($TL = 75.77 \pm 1.75$ cm), 22 (47.8%) were aged as 3 year old ($TL = 82.62 \pm 4.29$ cm) (Fig. 5) and age class 4 was represented by 8 specimens (17.4%) ($TL = 94.35 \pm 9.83$ cm).

Growth

The parameters of von Bertalanffy growth curve fitted to total lengths at age were estimated as: $TL_\infty = 102.39$ cm, $k = 0.4931$ year^{-1}, $t_0 = -0.5741$ years (Fig. 6). The theoretical asymptotic total length ($TL_\infty = 102.39$ cm) gave results lower than the largest specimen ($TL = 107.5$ cm) caught in this study. The value of the growth performance index obtained for all individuals was: $\Phi' = 3.7134$.

The relationship between weight and length estimated for *F. commersonii* in the study area is expressed by the equation: $W = 0.0001\ TL^{3.372}$ with $R^2 = 0.857$ (Fig. 7). This species showed positive allometry since the value of b = 3.372 resulted highly significantly different from the value 3.0, as confirmed by Student's t-test ($t_{58} = 4.133$; $p < 0.01$).

DISCUSSION

The present study provides new information on biology and ecology of the invasive Lessepsian fish *F. commersonii* from the central Mediterranean Sea. Since 77 specimens may not be representative of the whole population and reflect a first stage of range expansion, results should be considered as preliminary data.

Diet analysis indicated that bluespotted cornetfish is exclusively piscivorous in the study area, as found in other Mediterranean areas (Corsini *et al.*, 2002; Bariche, 2007; Psomadakis *et al.*, 2009), although some authors observed a secondary predation on crustaceans (Kalogirou *et al.*, 2007; Bariche *et al.*, 2009). Predation on the clupeid *Sardinella aurita*, the sparid *Boops boops* and centracanthids indicates the propensity of *F. commersonii* to catch pelagic species, although benthic and nectobenthic fishes, such as labrids and other sparids, are also well represented in its diet. Such feeding behaviour follows the same pattern adopted by this species in its native habitat (Takeuchi, 2009), where *F. commersonii* shows a foraging activity mainly focused on two types of prey fishes: reef fish that typically dwell on or near substrata (e.g., Tripterygiidae, Labridae) and pelagic fish that shoal in the water column (e.g., Clupeidae, Carangidae). Prey fishes were mainly juveniles, as showed by their size; only three species [*S. aurita, Thalassoma pavo* (Linnaeus, 1758) and *Symphodus ocellatus* (Forsskål, 1775)] were also found at the adult stage. The wide array of prey fish belonging to different habitats testifies to the high flexibility of *F. commersonii* in the choice of its prey. The significant correlation found between predator size and prey size suggests ontogenetic changes in the diet of *F. commersonii*, as previously reported in the Aegean Sea and in southern Japan (Kalogirou *et al.*, 2007; Takeuchi, 2009). In particular, these changes may be related to the diversification of foraging behaviours when body size of bluespotted cornetfish increases, due not only to the habitat types and anti-predatory behaviours of prey fishes, but also to associative foraging with con- or heterospecifics, which improves its foraging success (Takeuchi, 2009).

The analysis of feeding habits in non-indigenous invasive fish assumes particular importance in individuating potential competition for food resources with native species, which may be damaged by the presence of a new competitor in the own trophic niche. This event may have effects on the ecosystem equilibrium and also on human activities such as fishery. Therefore, future studies should investigate this aspect in order to understand which native fish populations and fishery resources are affected by invasive species.

To date, we could not find any study dealing with bluespotted cornetfish ageing in the literature. Fish of tropical waters are difficult to age because they grow in constant water temperature all year round and, consequently, the formation of growth increments (i.e. annuli) is compromised (Smith and Heemstra, 2003). However, our specimens collected in Sicilian waters, where temperature varies seasonally, should have been subjected to annual variation of faster growth in summer and slower growth in winter, like happens to fish of temperate waters. As expected, the vertebrae of these individuals displayed concentric marks (i.e. bands or rings) that can be due to annual growth increments. By means of vertebrae readings, we estimated the age of *F. commersonii* varying from 2 to 4 years within the size range of examined specimens. The maximum total length in the study area was 107.5 cm, corresponding to 4 years, although its maximum size reported in literature (i.e. 160 cm total length)

(Fritzsche and Schneider, 1995) suggests that this species may live longer than estimated.

The analysis of growth rates indicates that bluespotted cornetfish is a fast-growing species (k = 0.49 year^{-1}). The theoretical asymptotic total length (TL_∞ = 102.39 cm) was lower than the observed maximum (107.5 cm). This is possibly due to the low number of large individuals in our sample, as only two specimens outnumbered the TL_∞ value.

Regarding weight-length relationship, our results show positive allometry, indicating that bluespotted cornetfish becomes heavier for its length as it increases in size (Wootton, 1990). Positive allometry for *F. commersonii* were also found in Israel (b = 3.406) on 1073 specimens (Bariche and Kajajian, 2012) and in Lebanon waters (b = 3.35) on 47 individuals (Edelist, 2012), contrarily to results of Erguden *et al*. (2009), who reported a value of b = 2.504 on 12 specimens from Turkish waters. Possibly, the best estimate is the one published by Bariche and Kajajian (2012) given the high number of specimens analysed, distributed in a wide range of sizes and periods. These authors also calculated regression coefficient by sex, obtaining similar results (b = 3.398 for males, b = 3.352 for females). However, differences in growth patterns in relation to the sampling area are expected, since growth is strongly influenced by environmental parameters (e.g. temperature, salinity, etc.). A comparison of growth rates and age parameters between invaded areas and native waters will be possible only if new studies on age and growth of bluespotted cornetfish are carried out.

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